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STUDIES IN ASTRONOMY,

A LECTURE

ELABORATED FOR GENERAL READERS.

BY ARTHUR K. BARTLETT.

PUBLISHED BY THE AUTHOR.

BATTLE CREEK, MICHIGAN.

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STUDIES IN ASTRONOMY:

— BEING —

A Lecture on the Science, Elaborated with Numerous Additions for General Readers;

— EMBRACING ITS —

SUBLIMITY, HISTORY, PROGRESS, WONDERS, AND UTILITY,

TOGETHER WITH AN EXPLANATION OF

SPECTRUM ANALYSIS,

— AND A DISCOURSE ON —

EVOLUTION IN THE SKY,

— INVOLVING THE —

GROWTH AND DECAY OF WORLDS,

Considered under the Light of Recent Scientific Researches.

8/1451

By ARTHUR K. BARTLETT,

Astronomical Correspondent, Author of "The Science of Astronomy," Member of the American Association for the Advancement of Science, and Honorary Member of the Detroit Astronomical Society.

"I shall straight conduct you to a hill-side, laborious indeed at the first ascent, but else so smooth, so green, so full of goodly prospect and melodious sounds on every side, that the harp of Orpheus was not more charming."—*Milton.*

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SECOND EDITION.

Revised, Re-written, and Enlarged.

PUBLISHED BY THE AUTHOR.

BATTLE CREEK, MICHIGAN.

[1881]

TO MY ESTEEMED FRIEND,

EDWARD M. BRIGHAM,

IN RECOGNITION OF HIS ENTHUSIASTIC DEVOTION TO SCIENCE,
AND THE SERVICE HE HAS RENDERED TO EDUCATION
BY HIS JOURNEYS TO SOUTH AMERICA,
RESULTING IN VALUABLE ADDITIONS TO THE NATURAL
HISTORY COLLECTIONS OF MICHIGAN;

ALSO,

AS A SLIGHT ACKNOWLEDGMENT OF THE
SYMPATHY AND ENCOURAGEMENT WHICH I HAVE RECEIVED FROM
HIM IN MY SCIENTIFIC STUDIES, THIS LITTLE WORK IS

Most Gratefully and Affectionately

DEDICATED.

B 51
1931

STUDIES IN ASTRONOMY.

INTRODUCTION.

"The heavens declare the glory of God; and the firmament showeth his handywork." PSALM XIX, 1.

LADIES AND GENTLEMEN:—

The subject to which I have the pleasure of inviting your attention, is not only sublime, but one of stupendous magnitude. I intend to speak upon the general subject of astronomical science,—its sublimity, its history, its progress, its wonders, its utility, and its encouraging prospects for still further advancement in the distant future. If those present will but give me their earnest and unbroken attention while I introduce them in succession to the grand truths of astronomy, my task will be an exceedingly pleasant one.

Astronomy is the most ancient of all sciences. The study of the stars is doubtless as old as man himself, and hence neither history nor tradition can inform us concerning the first discoveries in this sublime science. Astronomy is a study which has in all ages engaged the attention of the most learned men of the world. "Kings have descended from their thrones to render it homage, and have sometimes enriched it with their labors; and humble shepherds, while watching their flocks by night, have beheld with rapture the blue

vault of heaven, filled with its thousands of shining orbs, moving in silent grandeur, until the morning star announced the approach of day." There is probably no human being who has for the first time turned his eyes toward the nocturnal sky, and beheld the moon "walking in brightness" among the hosts of stars and planetary orbs, marking off the hours, minutes, and seconds with an accuracy which no clock can ever rival, but must have been struck with awe and admiration at the splendid scene.

Who has not looked up to the celestial vault on a calm, bright night, when "the immeasurable heavens break open to their highest, and all the stars shine," and said to himself, "What are these far-off lights?" Are they worlds similar to our own, or merely lights placed in the heavens by some invisible being, for the purpose of exciting our reverence and admiration? What are their distances from our earth, and are they governed by the same laws which characterize the world we inhabit? If these are worlds, can they be peopled by wise and intelligent creatures like ourselves? and does the Almighty rule over their destiny as he does over our own? These, and similar questions, will naturally present themselves to all persons who allow their thoughts to soar among the star-depths. Even the little babe, in its weak and puny mind, looks up to the starry heavens, and perceives the beauties which they disclose, while filled with wonder and admiration. Many persons ask if these great celestial mysteries will ever be revealed to us, while others seem wholly unconcerned about them. A large number of these grand problems have already been solved, while others yet await the patient astronomer, whose keen eye, in gene-

rations to come, shall be able to read the mysteries therein. The heavens are before us, inviting our study, and waiting to make known unto us the grandest revelations of science.

Some enthusiastic writer has made the following truthful remark: "Perhaps there is no subject upon which the people are so profoundly misinformed as that of astronomy. Night after night they gaze up into the starry depths with as much intelligence as they would bestow upon a spangled wall-paper,—in fact, a degree less; for in the one case, they know that they are spangles, and in the other, they gaze on beautiful vacancy." The best reason known why so few persons care to study astronomy, is because the heavenly bodies can be so easily observed upon a clear sky. Prof. Henry Whitall, of New York, the inventor of the well-known "Movable Planisphere," so extensively used in the United States, makes the following true and interesting remark: "If there were but one spot on the earth where the gorgeous heavens were visible, and that a small place no larger than the State of New Jersey, there would not be a college in our land that would dare to graduate a pupil without that pupil being able to describe the wonders within that little State; and the education of no pupil would be considered complete until he had made a visit to see the beautiful stars which were visible on a clear evening within that little place." Because all can behold for themselves the starry heavens spread out to their view, is the principal reason why so few care to become acquainted with what all may see and know. The earth has the gift of captivating us so strongly, that we willingly forget the heavens for it. If sometimes we allow ourselves to be exalted by the wonders

of the skies, we quickly return to the things of earth, forgetting our grand celestial questions.

"When morning sheds its gorgeous dye,
Our hope, our heart, to earth is given;
But dark and lonely is the eye
That turns not, at its eve, to heaven."

The Sublimity of Astronomy.

Nothing can be more grand, more awe-inspiring, than the contemplation of the starry heavens. The study of the stars is the most ennobling within the range of speculative science. The mind that rises to the skies seems to soar above the littleness of earthly things, and in communing with the wonders of apparently silent but everlastingly rolling nature, one becomes purified, elevated, and in every way nearer to "the fear of God," which "is the beginning of wisdom." Concerning the sublime and inspiring aspect of astronomy, Prof. Richard A. Proctor, the eminent English astronomer, very eloquently remarks, while referring to the beauties of the starry heavens: "The mind cannot but be strengthened and invigorated, it cannot but be purified and elevated, by the contemplation of a scene so full of magnificence, imperfect though the means be by which the wonders of the scene are made known to us. The information given by the telescope is indeed but by piecemeal, and as yet no adequate attempts have been made to bring the whole array of known facts as far as possible into one grand picture; but, seen as it is, only by parts, and (even so) only as through a veil and darkly, the scene presented to the astronomer is the

grandest and the most awe-inspiring which man can study."

The starry heavens present an aspect which has been admired for its beauty by the poets in all ages. Thus wrote Byron, in his "Childe Harold's Pilgrimage":

"Ye stars! which are the poetry of heaven,
If, in your bright leaves, we would read the fate
Of men and empires,—'tis to be forgiven,
That in our aspirations to be great,
Our destinies o'erleap their mortal state,
And claim a kindred with you; for ye are
A beauty and a mystery, and create
In us such love and reverence from afar,
That fortune, fame, power, life, have named themselves
a star."

Every person should possess a certain knowledge of the starry heavens. The late Thomas Carlyle, the eminent author of England, regretted in his old age that he never learned the grand lessons of astronomy, and he said: "Why did not somebody teach me the beautiful constellations, and make me at home in the starry heavens, which are always overhead, and which I do n't half know to this day." These are the words of a distinguished scholar, and how many a man can say the same to-day! What person would not exclaim with the poet Virgil,

"Give me the ways of wandering stars to know,
The depths of heaven above, and earth below"?

The Work of Astronomers, and their Longevity.

Few persons can realize the great work which is being performed by astronomers in various parts of the world. Go to some large observatory at night, and if you are a

favored visitor, you shall peep in at the solitary explorers of the universe, as they sit, in separate apartments, perched high upon curious ladders, or crouched in quiet corners. Their eyes are glued to apertures which are the windows looking out upon the infinite. When obscuring clouds do not sweep across their field of vision, they will remain whole nights rooted to their places, pausing only to shift their machinery, or to jot a few memoranda, until the kindly light of morning drives their beloved stars from sight, and themselves to their repose. While the world sleeps around them, they pore, and strain, and study night after night, year after year. Proud to contribute their mite to the fund of the world's information, they will lay them down to their final rest, happier than emperors, if they have but discovered some few new planets, or more clearly demonstrated the character and movements of the older ones. Many of these "star-gazers" have bent over their books and machines until they have grown gray in their work, and extreme old age is now upon them.

Most persons would naturally suppose that a study which requires such constant attention, often robbing the astronomer of his peaceful hours of slumber and repose, would somewhat abridge the period of life. But astronomers, as a class, are noted for their longevity, and generally outlive all other men. It is a remarkable fact, well worthy of notice, that distinguished astronomers most often die between the ages of seventy and eighty-five. Sir William Herschel, the greatest astronomer of modern times, died at the advanced age of eighty-three; and so did Lalande, who, it is said, often remained whole nights in his attic for the purpose of studying the stars and planets. The late Sir John

Herschel (son of Sir William) died at the age of seventy-nine; and Prof. Airy, the eminent Astronomer Royal of England, is still living at a "ripe old age." The late Prof. Olmsted, of Yale College, in his excellent work, "Letters on Astronomy," said: "I know not how to account for this fact, unless we suppose that the study of astronomy itself has something inherent in it, which sustains its votaries by a peculiar aliment."

Every person who pursues this sublime study can read a noble lesson in the distant skies. But those who receive their knowledge of astronomy merely second-handed,—turning aside from the worry and excitement of a business life, to hear what a "star-gazer" has to say,—are unable to fully realize the grand truths which the heavens unfold to professional astronomers in their great observatories. Prof. Agassiz, the eminent old scientist, who has now gone to his rest, has made the following impressive remarks: "The glance at the moon, or at Jupiter's satellites, which the chance visitor at an observatory is allowed to take through the gigantic telescope, reveals to him nothing of the intense concentrated watching by which the observer wins his higher reward. The nightly vision of the astronomer, revealing myriad worlds in the vague, nebulous spaces of heaven, is not for him; he must take the great results of astronomy for granted, since no astronomer, capable of original research, has the time to prepare for the uninitiated the attendant circumstances essential to his more difficult investigations, or to train their eyes to see what he sees."

A Brief History of the Science.

Nothing can be more interesting in astronomical science than to trace its history and wonderfully rapid progress. For a long period, during the infancy of this science, comparatively little was known of the celestial bodies excepting their apparent motions and aspects. Instead of investigating with care their true motions and relative distances and magnitudes, many of our ancestors looked up to the sky, either with a brute, unconscious gaze, or viewed the heavens as a book of fate, in which they might read their fortunes, and learn, from the signs of the zodiac, and the various aspects of the planets, the temperaments and destinies of men, and the fate of empires. Even to this day, and in our own civilized country, the foolish art of "casting a horoscope," and prognosticating fortunes by the stars, is one of the principal uses to which the science of the heavens is applied.

The subject of astronomy is so vast and inexhaustible that it cannot be dealt with in a single lecture; and in tracing the history of this science, I shall speak only of those most important facts which will best enable my audience to understand its progress and glorious achievements. Prof. O. M. Mitchell, the celebrated astronomer, who established at Cincinnati the first observatory of any importance in the United States, and died in the defense of his country, has thus pictured, in eloquent language, man's first view of the starry heavens:—

"Often have I swept backward, in imagination, six thousand years, and stood beside our Great Ancestor, as he gazed for the first time upon the going down of

the sun. What strange sensations must have swept through his bewildered mind, as he watched the last departing ray of the sinking orb, unconscious whether he should ever behold its return. Wrapt in a maze of thought, strange and startling, his eye long lingers about the point at which the sun had slowly faded from his view. A mysterious darkness, hitherto unexperienced, creeps over the face of nature. The beautiful scenes of earth, which through the swift hours of the first wonderful day of his existence had so charmed his senses, are slowly fading, one by one, from his dimmed vision. A gloom deeper than that which covers earth, steals across the mind of earth's solitary inhabitant. He raises his inquiring gaze toward heaven, and lo! a silver crescent of light, clear and beautiful, hanging in the western sky, meets his astonished eye. The young moon charms his untutored vision, and leads him upward to her bright attendants, which are now stealing one by one from out the deep blue sky. The solitary gazer bows, and wonders, and adores. The hours glide by—the silver moon is gone—the stars are rising—slowly ascending the heights of heaven, and solemnly sweeping downward in the stillness of the night. The first grand revolution to mortal vision is nearly completed. A faint streak of light is seen in the east—it brightens—the stars fade—the planets are extinguished—the eye is fixed in mute astonishment on the growing splendor, until the first rays of the returning sun dart their radiance on the young earth and its solitary inhabitant. To him 'the evening and the morning were the first day.'"

Ancient Astronomers and Their Theories.

What a grand, imaginary description of man's first view of the starry heavens! But, let us now consider what the human mind has accomplished during its long and patient struggle of six thousand years. Generation after generation has passed away, age after age has swept silently by, but each has swelled, by its contribution, the stream of astronomical discovery. There is reason to believe that astronomy was studied by the antediluvians. It is certain that this science was cultivated in Western and Central Asia, within two or three centuries after the flood. Noah, probably, communicated some knowledge on the subject to his descendants. There was an ancient tradition that the patriarch Abraham was somewhat acquainted with this science; and it is evident that Job, a little later, was not ignorant of it, as may be seen from the Scriptures. History also informs us that the people of India understood astronomy, to some extent, eighteen hundred years before the Christian era. But the first careful observers of the heavens were the ancient shepherds, who, as they watched their flocks at night beneath the celestial canopy, naturally became interested in the orbs with which it was studded, and gave names to those that were most conspicuous. They knew, however, only such isolated facts as were apparent to the eye. It was reserved for later years to trace visible effects to their causes, and to advance theories; and not until the improved instruments of comparatively recent times extended the field of human vision almost beyond belief, was it possible to penetrate the mysteries of the heavens to their depths.

In this enlightened age of the world, the ideas of the ancients respecting the starry heavens appear absurd and almost incredible, and we can hardly understand how they could have been seriously entertained. The Chaldeans and Egyptians were the first to make any material progress in astronomy, and they were particularly distinguished for the accuracy and extent of their observations. The former, by continued observation, discovered that the eclipses of the moon recur in the same order, at intervals of eighteen years, and were thus able to predict them with considerable accuracy; the latter investigated the motions of the planets, and established a sacred year of 365¼ days. The Chinese, also, paid great attention to this science in very early times, and these people boast much of their astronomical discoveries. They have the earliest record of a solar eclipse, which occurred about 220 years after the flood. More than 2300 years before the Christian era (according to their own records), a tribunal was established for the prosecution of astronomical studies, and particularly for the prediction of eclipses; and it is reported that one of their kings actually put to death his two chief astronomers because they had failed to calculate an approaching eclipse of the sun.

Advancement in Knowledge.—The "Copernican System."

From Egypt, the cradle of learning, science, and art, the Greeks obtained their first knowledge of astronomy. Thales, about 600 years before Christ, taught that the world was round, and that the moon shone by reflected light, borrowed from the sun. "He introduced the division of the earth's surface into zones," and first

propounded the theory of the obliquity of the ecliptic. He also established the first school of astronomy in Greece. Anaximander, one of his pupils, conceived the bold idea that the planets are inhabited. Pythagoras, a little later, first conceived a system of the universe, which was in many respects correct, and he is said to have advanced the idea that the planets revolved round the sun. But he advanced no proof in support of his views, and they were soon well-nigh forgotten. Among other celebrated Greek astronomers were Eratosthenes, who devised an accurate method for measuring the circumference of the earth; and Hipparchus (known as the "Patriarch of Astronomy," and the "Newton of Antiquity"), who calculated the length of the tropical or solar year to within six minutes, discovered the precession of the equinoxes, and made the first catalogue of all the conspicuous stars visible above his horizon,—1081 in number. He also recorded the respective latitudes and longitudes of 1022 stars, together with their apparent magnitudes, and has been justly regarded as the most eminent of the ancient astronomers. Ptolemy, an eminent Egyptian astronomer, who flourished in the second century after Christ, rejected the theory of Pythagoras respecting the Solar System, and advanced one of his own, which soon met with general acceptance. He taught that the earth was the center of a system of eight immense hollow spheres of crystal, placed one within another; that the moon was in the nearest sphere; Mercury in the next; Venus in the third; the sun in the fourth; Mars, Jupiter, and Saturn in the fifth, sixth, and seventh respectively; and that the eighth belonged to the stars, which, though most distant, were still visible through the transparent

crystal. The revolution of this cumbrous system around the earth from east to west, once in twenty-four hours, he thought would account for the succession of day and night, and the various phenomena of the heavens.

During the Dark Ages of the world, when every man was his own astronomer, this science was cultivated chiefly by the Arabians, who made no advance as regards theory, but were diligent observers, and devised some improvements in instruments and methods of calculation. Even after the termination of this period, comparatively little progress was made until the time of Copernicus, a German priest, over 350 years ago. He ventured to reject the system of Ptolemy, which was still taught in all the institutions of learning in Europe, and reviving the teachings of Pythagoras, set forth what is called the "Copernican System," now very generally received as true by astronomers, although at first bitterly denounced as visionary and even irreligious. "For over forty years, this illustrious astronomer carried on his observations in the upper part of a humble, dilapidated farm-house, through the roof of which he had an unobstructed view of the sky. The work containing his theory was finally published just in time to be laid upon his death-bed." The three fundamental points of the "Copernican System" are: First, that the earth is round; second, that it turns upon its axis from west to east; and third, that the earth and all the other planets revolve around the sun as a center.

Some Important Discoveries.—Kepler, Galileo, and Newton.

After Copernicus came Tycho Brahe, a celebrated Danish astronomer, who propounded a theory in modification of the "Copernican System," and believed with Ptolemy that all the celestial bodies revolved about the earth as a center, in circular orbits, from east to west, every twenty four hours. This astronomer had a pupil named Kepler, who rejected the theory of his master; and advocating that of Copernicus, finally enunciated three grand truths of planetary motion, known as "Kepler's Laws,"—the result of eighteen years' assiduous and toilsome observation. A full explanation of these great laws, in order to render them comprehensible, would require a series of diagrams, and more time than could be given to the subject within the limits of a single lecture; but I will state them to my audience, in the order of their discovery, as follows:—

First,—ALL THE PLANETS, INCLUDING THE EARTH, REVOLVE IN ELLIPTICAL ORBITS, WITH THE SUN SITUATED AT ONE OF THE FOCI.

Second,—THE RADIUS VECTOR OF EVERY PLANET,—THAT IS, AN IMAGINARY LINE JOINING A PLANET WITH THE SUN—DESCRIBES EQUAL AREAS IN EQUAL TIMES.

Third,—THE SQUARES OF THE PERIODS OF REVOLUTION OF THE PLANETS AROUND THE SUN, ARE PROPORTIONAL TO THE CUBES OF THEIR MEAN DISTANCES FROM THE SUN.

These three laws are the foundation of our astronomical knowledge, and form one of the most glorious achievements of the human mind. When Kepler fully

realized the vast importance of his discoveries, he was completely overwhelmed with emotion, and at last, in the wild excitement of his glorious triumph, the great philosopher of the heavens exclaimed: "Nothing holds me; I will indulge my sacred fury! If you forgive me, I rejoice; if you are angry, I can bear it. The die is cast. The book is written, to be read either now or by posterity, I care not which. It may well wait a century for a reader, since God has waited six thousand years for an observer!"

Contemporary with Kepler was the celebrated Italian astronomer, Galileo, who improved and first made practical use of the telescope, with which he was enabled to make many brilliant discoveries, all tending to support the theory of Copernicus. He directed his telescope toward Jupiter, and discovered four satellites accompanying this planet in its revolution around the sun—a beautiful "Copernican System" in miniature, hung up in the heavens for all to see and examine for themselves. Who has not heard of

"The starry Galileo with his woes"?

The discoveries of this great astronomer met with the most bitter opposition. Because he believed that the earth revolved around the sun, and turned upon its axis, he was obliged to appear at Rome, and answer before the Inquisition for his seemingly absurd ideas. It was there that Galileo, a feeble old man of seventy years, kneeled down before the Cardinals, and with his hand upon the Bible, declared that he "abjured, detested, and abhorred the heresy of the earth's motion around the sun." But, as the old, gray-headed philosopher tottered out from the presence of the tribunal, it

is said that he muttered to himself, "*E pur si muove*,"—and yet the earth *does* move. This is now an evident fact, and so the whole world believes to-day.

The day on which Galileo died was memorable for the birth of Sir Isaac Newton, who discovered the grand law of "Universal Gravitation" which explained the planetary motions. Other astronomers had prepared the way, and it was reserved for Newton to make this important discovery, which gave a new impetus to astronomical science; or, in the words of the poet:—

> "Nature and Nature's laws lay hid in night:
> God said, 'Let Newton be,' and all was light."

Perplexing Movements of the Planets.

After all the brilliant discoveries had been made in relation to the Solar System, nothing was more difficult for the ancient astronomers to explain than the apparent motions of the planetary bodies. If the position of any planet among the stars be carefully observed from night to night, it will be noticed that it does not always move in one direction through the heavens, but will sometimes be observed to direct its motion toward the east for a certain period of time, and then suddenly halt in its course, remain stationary for a while, and begin to move in retrograde order toward the west, continuing in that direction until it will again come to a very sudden stop, and then, after remaining without the least apparent motion for another short interval, commence to retrace its course toward the east as before. Such are the apparent movements of these far-off worlds as observed from the earth. All the planets revolve around the sun in one direction,—*from west to east.*

Why, then, do they sometimes appear to move over the sky, from west to east, then halt, remain stationary, and after a short interval, direct their course toward the west, contrary to the direction in which they at first appeared to move? This is a question which, for many generations, puzzled and perplexed the ancient readers of the sky. They knew very well (as taught by old Copernicus) that the planets moved about the sun as a center, and also in the same direction; but the most intelligent and best informed of the ancient astronomers could not explain the peculiar and complicated movements of the planets as observed from our earth. Their knowledge of the heavens slowly increased, and it was finally surmised that the peculiar and unexplained motions which characterized the planetary bodies were owing to the fact that we did not observe them from the center of their orbits, but from the earth, which was also constantly shifting its position in space, and causing them to move with *apparent irregularity through the sky*. These were their views, and they have since been demonstrated to be correct. If, then, we could observe the planets from their center of motion,—the sun,—we should perceive these bodies moving around us at various distances, but all in the same direction,—from west to east.

Modern Astronomy. — Discovery of the Planet Uranus.

Having thus briefly traced the history and progress of ancient astronomy, let us now consider some of the modern discoveries in this science, which clearly illustrate the ability of man to grapple with the grand problems of the skies. There is nothing more encouraging in

the history of astronomical science than the remarkable success which has rewarded the observations of modern astronomers. From the earliest ages, the mighty orbit of the planet Saturn was supposed to form the boundary of the Solar System. The slow and majestic motion of this planet, its great period and distance, and the wonderful magnificence of its rings and moons, seemed to render it a fitting object to guard the frontiers of the mighty system with which it was associated. But it is a well-known fact, as the result of Newton's grand discovery, that all the planets exert an attraction upon each other, and produce certain orbital disturbances, which are called perturbations. Near the close of the eighteenth century, when the planetary motions had been observed with great care, and a comparatively accurate knowledge of their perturbations had been acquired, certain unexplained motions of Saturn gave rise to the belief that another planet revolved around the sun in a vast orbit far beyond that of Saturn. On the 13th of March, 1781, while Sir William Herschel was engaged in examining some stars in the constellation Gemini, his attention was attracted to a small star of remarkable appearance, which fortunately happened to pass into the field of his great telescope. He examined the strange star with higher magnifying powers, when it appeared greatly increased in dimensions, and exhibited a sensible disk. After watching it for several evenings, Herschel noticed that its position changed among the stars, and not even dreaming that the body was a planet, he announced to the world that he had discovered a new and remarkable comet. But it required only a short time to convince the astronomical world that the body in question was a member of the Solar System. It is

now known as the planet Uranus, represented in the illustration* before you as the seventh in order of distance from the solar orb. This planet is situated at a mean distance of 1771 millions of miles from the sun, and requires eighty-four of our years to complete its vast circuit around that luminary. Here is a brilliant astronomical discovery, which may be regarded as the result of a merely accidental observation.

Another Brilliant Discovery.—The Planet Neptune.

We will now consider a still more remarkable discovery, which is regarded as one of the most glorious achievements of the human mind. For many years after the discovery of Uranus, the movements of this planet were such as to baffle the most accurate calculations. While the planet Saturn came around to its place true to the minute and second, even after its journey of nearly thirty years, it was found that the planet Uranus did not strictly conform to the path assigned to it. It was finally suggested by several astronomers that another planet revolved around the sun outside the orbit of Uranus, which disturbed the movements of this planet, and produced its perturbations. The disturbing influences of Jupiter and Saturn, the only planets which could affect the motions of Uranus appreciably, had been taken into account; and the masses of these plan-

*In delivering this lecture, the subject was illustrated with large oil paintings; and although the original references to them are retained, it has been thought unnecessary, in preparing the lecture for publication, to introduce diagrams, as some alterations have been made which will doubtless render the explanations clear without them.

ets had been far too satisfactorily ascertained to leave any doubt as to the effects which they could produce on Uranus. Sir William Herschel had carefully studied the movements of Uranus, and so firmly did he believe in the existence of another planet, more remote from the sun, that he remarked: "We see it as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis, with a certainty not far inferior to occular demonstration."

It is one of the most difficult problems presented to an astronomer "to determine the motions of a planet when all the circumstances which can affect that motion are known." The great problem presented to the astronomer was this: "Given the disturbances produced by the attraction of an unknown planet, to find its orbit, and its place in the orbit." Only two astronomers in the world were bold enough to attempt the solution of this problem. These two were Leverrier, of France, who died recently at the age of sixty-eight, and Adams, of England, both young mathematicians, who, each unknown to the other, undertook the difficult task of finding the place of the supposed planet. Leverrier was not quite unknown to science in his own country, although comparatively at the beginning of his astronomical career. Adams was a scientific student of unusual ability, and was preparing to receive his degree at Cambridge University. None but those who understand the difficulties involved in a mathematical question of this kind, can fully realize the magnitude of the problem which was presented to these young men for solution. Adams first completed his calculations, after nearly two years of toilsome labor, and in October,

1845, he submitted them to Prof. Airy, the Astronomer Royal of England. A few months later, Leverrier presented his calculations to the Academy of Science in Paris, and announced the figure of the orbit of the supposed planet, its distance from the sun, its period of revolution, and even the mass of matter which it contains. On the 23d of September, 1846, Leverrier wrote to Prof. Galle, of Berlin, for assistance in searching for the imaginary planet, and requested him to direct his great telescope to a certain point in the heavens. Prof. Galle, on that same evening, did as requested, and after a few moments' observation, he discovered a star of the eighth magnitude, which he knew to be a stranger in that region of the heavens, as it was not laid down on the most accurate maps. This proved to be the predicted planet, which was discovered within less than two diameters of the moon's disk from the spot indicated by Leverrier, or what would appear to be about one foot, as seen upon the sky.

It is but justice to young Adams to add, that after the discovery of this planet by Prof. Galle, he perfected his own calculations, and arrived at results almost identical with those of the French mathematician, although he was entirely unknown to him, and had pursued an independent train of reasoning. The brilliant discovery of this planet was the result of pure mathematical calculations, and fully demonstrates the power of the human intellect to comprehend the great laws of nature. Far sweeping in the depths of space, unseen by mortal eyes, this new world pursued its solemn journey, reflecting back the light of the solar orb, steadily obedient to the grand law of Universal Gravitation, which held the old planets true to their changing orbits.

This planet has received the name of Neptune. The news of its discovery spread in every direction, and filled the world with astonishment and admiration. Neptune is the most remote planet from the sun at present known to astronomers,—the far-off sentinel of the planetary system. It requires 165 of our years to complete a single revolution around the sun, at the enormous distance of 2775 millions of miles. Such is a brief history of one of the grandest achievements of the human mind, and the world will always be glad to honor the names of Leverrier and Adams, who, by their remarkable knowledge of the mathematics of the skies, won for themselves an enviable fame, and a position in the foremost ranks of modern astronomers.

Spectrum Analysis Explained.—Important Researches.

We now come to the most wonderful discovery in modern astronomical science since the planet Neptune was added to the solar system. The ancient astronomers never dreamed that the constitution of the stars and planets would ever be ascertained. But even this astounding success has been achieved, and we are now permitted to speak—and speak with confidence—of "Celestial Chemistry," as made known to us by a new science called "Spectrum Analysis." By "spectrum analysis" is meant the chemical analysis of substances by means of a wonderful instrument known as the "Spectroscope." If a beam of white sunlight is allowed to enter a darkened room through a small aperture in the window shutter, and then passed through a triangular prism of glass, we find that it is separated into the seven colors of the rainbow. These, collectively, pro-

duce what is called the "Solar Spectrum." This may be easily formed by any person by procuring a triangular piece of glass, and allowing the sunlight to pass through it, when a most beautiful spectrum can be seen; or a somewhat similar effect may be produced by simply looking through one side of the glass toward a strong light; and the beautiful combination of colors which we observe is termed a "Spectrum," whatever the source may be from which the light is derived. What person has not amused himself by looking through the triangular glasses of a parlor chandelier, and observing the brilliant colors of the rainbow? This amusement, on a much larger and grander scale, has worked wonders in modern science, and enabled the astronomer to solve some of the most interesting problems of the skies.

The discovery of the solar spectrum was made by Sir Isaac Newton; but the beautiful coloring is only a small part of it. In 1802, the solar spectrum was found by Dr. Wollaston to be crossed, at right angles, by a large number of dark lines. These have been called "Fraunhofer's Lines," in honor of Prof. Fraunhofer, who mapped the plainest of them with great accuracy. In 1859, Prof. Kirchhoff, a distinguished German philosopher, discovered the real character of these lines, and their important significance respecting the physical constitution of the sun, stars, and planets. I now invite your attention to this illustration of the solar spectrum, which, I hope, will render clear the manner in which astronomers are able to ascertain the various substances existing in the celestial bodies. Here is represented a beam of white sunlight coming into a darkened room through a small slit in the window-shutter, and, upon

passing through a triangular glass prism, the beam is separated and spread out into a beautiful fan-shaped band of light, exhibiting all the colors of the rainbow. If a screen be suitably placed to receive the dispersed sunlight, we will find a beautiful rainbow-tinted streak, composed of seven colors, arranged in the following order, commencing at the top, and naming them downward in regular succession: Violet, indigo, blue, green, yellow, orange, red. This brilliant band of colors forms what is called the "solar spectrum." I have already stated that the "Fraunhofer Lines" observed in the solar spectrum are dark. When the light from an artificial source is passed through a prism, and its spectrum is examined by the spectroscope, no dark lines are visible, but instead of these, there will be seen lines of various bright and beautiful colors. The color of these lines, and their place in the spectrum, depends upon the *substance from which the light proceeds.* For example: If the metal sodium be burned in a hot gas flame, two bright yellow lines will always appear in the yellow part of the spectrum, while the metal potassium in the flame will always give two lines; one, of a brilliant crimson color in the red end of the spectrum; the other, a beautiful blue line far up in the violet end. It was also discovered that each substance burning invariably gave forth its *own peculiar system of lines.*

Upon these few facts rests the whole science of "spectrum analysis." Now, what is very remarkable, it was found that the position of these bright lines coincided with those of the dark lines in the solar spectrum. Here is a diagram of the spectrum given by the metal sodium in a vaporous condition. This is found to be

the quality of a spectrum given by a gaseous body. You will here observe the position of the two bright lines referred to. In the solar spectrum are found two dark lines which occupy precisely the same position as those of sodium. Various other substances giving bright lines, are also represented by dark lines in the solar spectrum. Now, what intelligence do these facts convey to the astronomer? It has been found that the dark lines of the solar spectrum indicate vapors cooler than the sun's mass, which intercept a portion of its light, and that the lines are produced by the absorption of light while passing through the sun's atmosphere. Thus arise the dark lines; and the astronomer only wants to know the *exact position of these lines* to ascertain what elements exist in the sun. The spectrum of a star also exhibits most of the dark lines found in the solar spectrum, which indicate that the stars are suns like our own. Most of the nebulæ and comets give a spectrum of bright lines, thus proving beyond a doubt that they are of a gaseous nature. By means of the spectroscope, astronomers have learned that all the celestial bodies have *nearly one identical constitution*, and possess many elements which exist and even sustain life upon our own world.

> "All are but parts of one stupendous whole,
> Whose body nature is, and God the soul."

Future Revelations of the Spectroscope.—Its Important Applications in Modern Science.

It is impossible to foresee what may yet be accomplished by the spectroscope,—the most wonderful and important instrument of modern science,—for, as an English astronomer has recently remarked, "Matters

of pure conjecture to-day may become entirely settled by the spectroscope to-morrow." It affords the most delicate and trustworthy means at present known for analyzing chemical substances, and has already revealed many new elements and substances before unknown to the chemist. So delicate is this instrument as a chemical test, that it will easily detect the $\frac{1}{2500000}$th part of a grain of sodium; and when all other means of analysis fail, the chemist then appeals to the spectroscope, with the most accurate and astonishing results. One of the most recent and important applications of the spectroscope to the science of astronomy, is its employment as a means of determining what stars are approaching and receding from the earth, which is regarded as one of the greatest and most interesting achievements of modern times in the department of stellar astronomy. The spectroscope divests the sunbeam of its mysteries, after traveling over ninety millions of miles, and reveals to us the chemical constitution of the planets, comets, and even the distant stars. To quote the eloquent language of Dr. Warren, author of a recent work on astronomy: "In the near future we shall have the brilliant and diversely-colored flowers of the sky as well classified into orders and species as are the flowers of the earth."

We thus see the vast importance of spectrum analysis. By a few mysterious, and at first unattractive lines, astronomers have been able to make the most wonderful discoveries of modern science. And silently these lines will continue to speak to us, and more and more intelligently and eloquently as we rise higher in the intellectual scale, and become better fitted to hold conversation with them. It is from our knowledge of spectrum

analysis that astronomy will reach us, and from the revelations of the spectroscope that the future progress of this science will advance.

The Grand Results of Astronomical Research.

Such have been the glorious achievements of modern astronomy. We have traced the wonderful progress of the human mind during its long and toilsome struggle of more than sixty centuries. One barrier after another has given way to the steady march of astronomical science, until the human mind, majestic in its strength, has mounted step by step up the rocky height of its self-built pyramid, from whose lofty summit it looks out upon the grandeur of God's universe! The grand results of human investigation cannot fail to fill the mind with astonishment, and to demonstrate the truthful passage of Scripture, that man has been made but a little lower than the angels. These brilliant achievements of astronomy have not resulted from the labors of any *one* astronomer. No *one* astronomer has ever grasped enough to accomplish much by himself. But each astronomer has done his own little part, all the more thoroughly because it has been so small, and the aggregate result is a grand one. What tribute can we now pay to the memory of that unknown mortal who first resolved to read and comprehend the starry heavens? To quote the eloquent language of Prof. Mitchell: "On some lofty peak he stood, in the stillness of the midnight hour, with the listening stars as witnesses of his vows, and there, conscious of his high destiny, and of that of his race, resolves to commence the work of ages. 'Here,' he exclaims, 'is my watch-tower, and yonder bright orbs are henceforth my solitary compan-

ions. Night after night, year after year, will I watch and wait, ponder and reflect, until some ray shall pierce the deep gloom which now wraps the world.' Thus resolved the unknown founder of the science of the stars. His name and his country are lost forever. What matters this, since his works, his discoveries, have endured for centuries, and will endure as long as the moon shall continue to fill her silver horn, and the planets to roll and shine?''

The Increasing Popularity of Astronomy, and Its Remarkable Accuracy.

Astronomy is now becoming more popular than ever before. This is by no means a matter of surprise, as no other science is doing so much to benefit the world at large. If any proof were needed that the people of this country are beginning to appreciate the value of astronomical knowledge, no greater could be found than the interest with which the beautiful comet of 1874 was observed, and the remarkable success which attended the popular lectures of Prof. Proctor, the eminent English astronomer, during each of his three visits to America. Night after night, this great scientist stood before crowded audiences in our largest cities, expounding the grand truths of modern astronomy, and rejoicing in his noble work. Astronomy is now the most perfect of the sciences, and hence astronomers are enabled to predict results with absolute precision thousands of years before they occur. They announce that on such a year, month, day, hour, minute, and second, a celestial body will occupy a certain position in the heavens. At the time indicated, we point our telescopes to the place, and at the exact instant, true beyond the

accuracy of any time-piece, the orb sweeps into view. Here permit me to exhort you in the beautiful language of the poet:—

> "Come forth, O man, yon azure round survey,
> And view those lamps which yield eternal day,
> Bring forth thy glasses, clear thy wondering eyes,
> Millions beyond the former millions, rise:
> Look further: millions more blaze from yonder skies."

It is not to be expected that all persons who pursue this charming study will eventually become celebrated astronomers; but it should be the duty of every votary in astronomical science, to record all known phenomena, to arrange and classify the facts, to discover, if possible, the relations of the laws which he observes; and if he cannot discover at once the sublime marvels of the heavens, he can classify all observations for other astronomers who succeed him, in order that they may themselves work with better hope of success. The small number of votaries in astronomical science should be increased. Every other profession is now full, and that of astronomy alone needs more enthusiastic workers. There are always certain persons who seem to be prejudiced against astronomy. They will not only shun this exalting science themselves, but even persuade others not to study it. Would that such persons could only appreciate Tennyson's beautiful lines:—

> "Let knowledge grow from more to more,
> But more of reverence in us dwell;
> That mind and soul, according well,
> May make one music as before,
> But vaster."

Inspiring Aspect of the Sky in Autumn and Winter.

I can think of nothing which seems better calculated to lead men to choose astronomy as a favorite subject of study, and to inspire one with an emotional love for this science, than the magnificent scenery of our nocturnal sky at this season of the year. During the autumnal and winter months, the starry heavens put on their grandest and most attractive appearance. The brightest stars in our firmament—fifteen being of the first magnitude—are at present visible upon the evening sky, and great constellations, meandering over a large extent of the heavens, continue above our horizon throughout the entire night, presenting a scene beautiful beyond description.

The evening sky in autumn and winter is glorious with its constellations. Toward the south, at an early hour in the evening, during the months of December and January, may be seen the beautiful constellations of Taurus and Orion. Overhead shine Auriga, Perseus, and Andromeda, with Aquila, Delphinus, Lyra, and Cygnus further west; and in the east are Lepus, Cetus, and Canis Major. These constellations alone include twelve stars of the first magnitude, all of which are above the horizon, and may be seen on every clear evening during the winter.

"Thus monstrous forms, o'er heaven's nocturnal arch
Seen by the sage, in pomp celestial march;
See Aries there his glittering bow unfold,
And raging Taurus toss his horns of gold;
With bended bow the sullen Archer lowers,
And there Aquarius comes with all his showers:
Lions and Centaurs, Gorgons, Hydras rise,
And gods and heroes blaze along the skies."

Compared with the grand appearance of our evening sky at this season of the year, the most resplendent terrestrial scenes sink into nothingness, and appear unworthy of being set in competition with the glories of the starry heavens.

The Practical Importance of Astronomy.

Do you now ask what is the practical utility of astronomical science? Many of the benefits derived from astronomical observations are perhaps too apparent in our day to need much explanation before an intelligent audience. Independently of the sublimity of its objects, and the pleasure arising from their contemplation, astronomy is a study of vast utility, in consequence of its connection with the terrestrial arts and sciences, many of which are indebted to the observations and the principles of this science for that degree of perfection to which they have attained. Prof. Steele makes the following impressive remarks, concerning the value of the stars in practical life: "The stars are the landmarks of the universe. They seem to be placed in the heavens by the Creator, not alone to elevate our thoughts, and expand our conceptions of the Infinite and Eternal, but to afford us, amid the constant fluctuations of our own earth, something unchangeable and abiding. Every landmark about us is constantly changing, but over all shine the 'eternal stars,' each with its place so accurately marked that to the geographer and astronomer no deception is possible. To the mariner, the heavens become a dial-plate, the figures on its face set with glittering stars, along which the moon travels as a shining hand that marks off the hours with an accuracy that no clock can ever rival. . . . In all the in-

tricacies of surveying, the stars afford the only immutable guide. Our clocks vainly strive to keep time with the celestial host. Thus, by a wise provision of Providence, even in the most common affairs of life, are we compelled to look for guidance, from the shifting objects of earth, up to the heavens above."—*Steele's Astronomy*, p. 233.

The great practical purpose of astronomy to the world consists in enabling us safely to navigate the ocean. Astronomy has proved of indescribable benefit to the navigator; for, without some knowledge of this science, he never could have traced his course over the great ocean to any far-distant land. It is of vast importance for the mariner to know on what part of the globe he is situated at any time in the mighty ocean; also to understand many other particulars which can be determined only by astronomical observations of the utmost accuracy. The following extracts from the writings of three different authors beautifully illustrate the utility of this science in its application to navigation, as well as to other benefits which we derive from it; and the first quotation describes one of the most important operations in practical astronomy:—

"Place an astronomer on board a ship; blindfold him; carry him by any route to any ocean on the globe, whether under the tropics, or in one of the frigid zones; land him on the wildest rock that can be found; remove his bandage, and give him a chronometer regulated to Greenwich or Washington time, a transit instrument with the proper appliances, and the necessary books and tables, and in a single clear night he can tell his position within one hundred yards, by his observations of the stars."—*Newcomb's Popular Astronomy*, p. 103.

"A ship that leaves our shores for a voyage around the world, takes with it a book called the 'Nautical Almanac,' prepared three or four years in advance by government astronomers. In this book, the places the sun, moon, stars, and planets will occupy at certain stated hours for each day, are given, and this information is all that sailors and travelers require to find their way across pathless seas or unknown lands. A prediction of the 'Nautical Almanac' is received with as much confidence as if it were a fact contained in a book of history. On the trackless ocean, this book is the mariner's trusted friend and counsellor; daily and nightly its revelations bring safety and happiness to ships in all parts of the world. It is something more than a mere book. It is an ever-present manifestation of the order and harmony of the great universe of God."—*Steele's Fourteen Weeks in Astronomy*, p. 308.

"But we need not go on board ship, or into new countries, to find out the practical uses of astronomy. It is astronomy that teaches us to measure the flow of time,—the length of the day and the year; without astronomy to regulate them, our clocks and watches would be quite useless to us. It is astronomy that divides the year into seasons for us, and teaches us the times of the rising and setting of the moon, which illuminates our night. It is to astronomy, also, that we must appeal when we would inquire into the early history of our earth, or wish to map its surface."—*Lockyer's Elements of Astronomy*, p. 15.

Astronomy has also been of great utility to the science of geography; for without a certain knowledge of the heavens, the true figure of our globe would never have been ascertained. The manner in which Colum-

bus discovered the rotundity of the earth was by observing its shadow during an eclipse of the moon. Before that time, most persons believed that the earth was a smooth and boundless plain, and that if its limits could be reached, they would fall into what was termed the "abyss of tartarus." But to-day the mighty ocean is traversed by steam and sail, and commerce is carried on in all parts of our civilized world.

Even religion has been greatly benefited by astronomy, without a knowledge of which, missionaries would never have been carried across the ocean to teach the heathen and other uncivilized people of the existence of a God. If any persons wish to be thoroughly convinced that a Divine Power *does rule supreme*, they need only direct their eyes upward to the nocturnal sky; for there is no better evidence of the existence of an Almighty Creator, than the precise structure and management of our starry heavens.

"View the amazing canopy!
The wide, the wonderful expanse!
Let each bold atheist agree
That God is there, unknown to chance."

Truly, "An undevout astronomer is mad." The study of astronomy is direct intercourse with the Master Mind, and the earnest devotee of this science is prepared to "look through nature, up to nature's God."

The Wonders of Astronomy.—Interesting Facts Regarding the Sun.

Let us now consider some of the wonders of astronomical science. To those who have given but little attention to the study of astronomy, many of the great

facts which I am about to state, will doubtless seem astonishing and almost incredible. I will first invite your attention to the wonders of the sun,—the great fountain of life, light, and heat of our planetary system. The diameter of this great orb is 860,000 miles. You will perhaps be able to understand these figures better by comparison. In this illustration, the larger circle is intended to represent the shell of the sun. Now, if we imagine our earth placed here at the center of the sun, there would be enough space for the moon to revolve in its regular orbit, represented by the smaller circle, at a distance of 240,000 miles, within the sun's circumference, besides leaving 200,000 miles stretching in every direction beyond! The volume of the sun is 1,245,000 times that of our earth; that is, it would require 1,245,000 earths to make a globe equal in size to that of the sun. The mass of the sun is 674 times that of all the other members of the solar system taken together. Recent calculations from observations of the last transit of Venus, which occurred in the year 1874, show that the distance of the sun from the earth is about 92,000,000 miles. Light, which travels with the almost inconceivable velocity of 186,000 miles every second, requires more than eight minutes to reach us from the sun. If an express train could start from the sun, and travel night and day, at the rate of thirty miles an hour, it would require 340 years to reach our earth. Prof. Proctor says that if an infant were born, having an arm 92,000,000 miles long, so as to reach the sun; and if, in the cradle, he were to lift out his arm and touch this luminary, that infant might grow to the threescore years and ten allotted to man, but he never would be conscious of the fact that the tip

of his finger was burned. He would have to live 135 years before that would be experienced. Perhaps it would be well for some infant to try this experiment just once, to see if the professor is correct!

The distance of the sun seems enormous to us; yet, it is used by astronomers as a *unit for expressing celestial distances!* We receive enough heat from the sun annually to melt a solid layer of ice 38 yards in thickness, extending over the whole earth. Sir John Herschel says, that if a solid cylinder of ice, 45 miles in diameter, and 200,000 miles long, were plunged, end first, into the sun, it would melt in a single second of time; and yet, it is interesting for us to know that the heat is 300,000 times more intense upon the surface of the sun than it is upon our earth, and also that we receive only the $\frac{1}{2300000000}$ part of the total energy—light, heat, and chemical activity—radiated by the sun in every direction throughout space. This glowing orb, which appears so small to us, is the scene of tremendous activity. Here on earth we sometimes witness fearful tornadoes; but there are atmospheric disturbances taking place on the sun, compared with which those of our earth are utterly insignificant. Is it a wonder, then, that persons once worshiped the sun, that great luminary whose rays bring so many blessings to us, and without which all life would cease to exist?

"Great source of day! best image here below
Of thy Creator, ever pouring wide,
From world to world, the vital ocean round;
On nature write, with every beam, His praise."

Wonders of the Star-Depths.—Motions of the Stars.

If these facts relating to the sun seem astonishing to you, the wonders of the star-depths will seem still more so. To ordinary vision, the stars appear at rest in our heavens; nor can the astronomer himself recognize any signs of motion, except by patient and long-continued observation, extending, in some instances, over a period of many years, and even centuries, when succeeding astronomers complete the work which their predecessors had begun. But every star in the firmament is on its journey, and moving through space with wonderful velocity. Absolute rest is unknown throughout the material universe. If we look up to the sky on a calm, bright night, when the stars shine forth in all their glory, we are usually impressed with the feeling that a solemn stillness reigns throughout those infinite depths. This is the idea suggested to the imagination of the poet; nor is any other view apt to present itself to those who are unfamiliar with the teachings of modern astronomy. But those amazing star-depths above us, which appear so steadfast and unchangeable from year to year, are astir with life, energy, and activity, and there is a wonderful process of change taking place all around us. Our own earth is moving with us constantly and rapidly in its orbit, eighteen miles per second, with nearly every beat of the pulse! This is our velocity as reported by the astronomers, and while we sleep seven hours, the world on which we dwell moves 470,000 miles! It is believed by many astronomers that the sun, with its family of planets and comets, is moving through space toward the constellation Hercules! In my explanation

of Spectrum Analysis, I stated that the spectroscope has shown what stars are approaching and receding from the earth. Among the stars found to be approaching the earth, is Arcturus,—mentioned in the Bible, and the brightest star in the northern hemisphere,—which is moving with a velocity of fifty-five miles every second. Sirius, the "Dog Star," and "King of Suns," so glorious on winter evenings, and the brightest star in the heavens, is receding from us at the rate of twenty-five miles a second; and yet, even with these enormous velocities, the passage of a million years will make no perceptible difference in the appearance of these two stars, so great are the distances which separate them from our earth!

The greatest velocity that has been recognized among the stars, is found in the motion of a star known as 1830 Groombridge,—or the "Runaway Star," as it is sometimes called,—which is believed to be rushing through space at the rate of two hundred miles per second. This star appears to be moving in a perfectly straight path through the sky, as do all of those stars which are found to have a "proper motion" independently of each other, and it may be visiting our stellar system for the first time; but whence it came, or whither it is going, no one can tell, and it is a great enigma to astronomers. Its wonderful velocity cannot be explained, and is greater than could be caused by the influence of all the known bodies in the universe; and on the other hand, the combined attraction of all the orbs of heaven cannot stop this star in its solitary flight through the sky, until it has rushed on to the extreme limits beyond which the greatest telescopes have never penetrated. Then, possibly, but not until then, will this remarkable

star yield to the overpowering attraction of the millions of suns which belong to our universe; but what will become of it in future centuries, when its enormous velocity has been so far reduced that its forces of resistance no longer hold supremacy, and finally become expended, it is beyond the power of man to conceive, unless we imagine that it will be compelled, by the attraction of another universe, to move in a new path, and continue on forever in its irresistible career.

It has been mathematically demonstrated, that a body approaching the center of our system, from an infinite distance, cannot move with a greater velocity than twenty-five miles a second, if influenced by the attraction of the masses in our universe alone; but here we are considering a star moving with eight times that velocity, and still, notwithstanding the fact that it has the greatest motion known among the stars, it would require 185,000 years for this star to complete an entire circuit around the heavens!

Our entire universe of stars is constantly undergoing vast changes, which will be perceptible to those who inhabit the earth in future centuries. The configurations of our starry heavens will eventually be greatly changed from their present appearance. Orion will then no longer hold supremacy over the constellations. The well-known "Big Dipper" will sometime, in the distant future, assume a different appearance from that now presented to our view, and must finally cease to attract the attention of thousands who to-day admire its beauty in our northern skies.

Evolution in the Sky.—The Growth and Decay of Worlds.

There are wonderful processes of evolution taking place in the star-depths. The work of creation has not yet ceased,—as many persons of bigoted religious propensities believe, who accept the Bible as the only reliable authority,—but is still going on before our eyes, and the heavens afford to our view the process of world-making in all its various stages. It is a remarkable fact that the idea of the gradual transmutation of nebulæ into stars was suggested to astronomers long before the doctrine of evolution had become fully established.

These paintings, to which I now invite your attention, are intended to illustrate the process of world-making in different stages of advancement. Here is a representation of the large, faint, and diffused class of nebulæ, irregular in outline, and of a cloudy aspect, in which the process of central condensation into stars seems to have hardly begun. Nebulæ of this description have been seen scattered over the heavens in great numbers, and the spectroscope shows that they are composed entirely of gaseous matter.

These nebulæ are stellar systems in their incipient stages of creation, and exhibit to us the crude material out of which worlds are made,—"world stuff" as it has been appropriately called by astronomers. This is the highly-attenuated nebulous substance out of which Laplace supposed our Solar System to have been evolved by gradual condensation, and upon which he founded his famous "Nebular Hypothesis," assigning the genesis of the sun and planet-family to a process of growth and development. Thus, when we observe these faint

nebulæ, we can see in the heavens the same kind of material under the very form once presented by our Solar System, according to the nebular hypothesis.

In this picture is shown the smaller but brighter class of nebulæ, which have so far condensed that the central parts will soon begin to form stars. Here is another kind in which stars have actually begun to form; and finally you see represented a star-cluster, in which the condensation is all completed.

This picture shows the appearance of the great spiral or "whirlpool nebula," in the constellation Canes Venatici, or the Hunting Dogs, one of the most wonderful objects to be seen in the heavens. It has two centers of condensation, around which the stars appear to be forming; and in this nebula we see indications of gigantic forces in operation, the nature of which is entirely unknown to astronomers. The number of spiral nebulæ known is not large, compared with the other forms which have been observed, but the one represented here is the largest and most interesting object of its class. To all appearances, it is rotating with great rapidity, as indicated by its spiral convolutions when seen through a large telescope, although no actual motion of the object can be observed. This nebula presents the very appearance which the nebular hypothesis assumes in accounting for the origin of our Solar System, and its spiral aspect would lead us to believe that it is a rotating mass, out of which a sun and system of planets will ultimately be evolved.

The next picture represents the great gaseous nebula in Orion, as it appears through a telescope in the High School building, at Battle Creek, Michigan. It was painted from a drawing which I made of this nebula,

with the aid of this instrument, over five years ago, and is a fair representation of the wonderful object as seen with a high magnifying power. Here you will observe four stars forming a beautiful "trapezium," where only one star can be seen with the naked eye; and here are three stars, arranged in nearly a straight line, which show how nebulous matter is observed to cling around certain stars, just as if the substance composing the nebula was drawn in from surrounding space in order to form these stars; and in such cases, we see a convincing demonstration that the work of creation has not ceased, but on the other hand we are able to recognize before our eyes the great processes of evolution which are still taking place all around us in the starry heavens.

An almost infinite variety of nebulous forms may be observed through the telescope; and although we cannot see any one particular nebula pass through all the stages of its progress, yet we can observe different nebulæ in each stage of advancement, and thus recognize the full process of their growth and development.

We cannot conceive how vast must have been the periods of time required for the formation of these wonderful nebulæ,—periods compared with which, even the Archæan, Paleozoic, Mesozoic, and Cenozoic times of geology, immense as they are known to have been, —shrink into insignificance, and seem but as moments in the flight of eternity! God does not do things in a hurry, but takes time, and works on slowly through the ages. He does not create a universe in six days, and then stop to rest, but, as a recent writer has well remarked, "He takes a thousand years to lift his hand off;" and it is by slowness that His most stupendous operations are accomplished. Surprising as it may seem to you,

it is nevertheless a fact that more nebulæ are now known and catalogued than there are stars visible to the naked eye in the whole heavens. About 6,200 of these objects are at present known to astronomers, and over two-thirds of this number were discovered by the two Herschels,—father and son—the elder Herschel having alone discovered and described 2,508 nebulæ and star-clusters during his brilliant career as an observer of the heavens.

Our own Solar System once formed part of a large nebula—according to the ingenious speculations of Laplace—and has been slowly condensed into its present proportions. Many of these far off nebulæ are believed to be distant universes, and the telescope reveals them in all conceivable forms, and degrees of condensation. A recent work on astronomy, by Rev. H. W. Warren, contains the following passage regarding evolution in the heavens: "Suns are of all ages. Infinite variety fills the sky. It is as preposterous to expect that every system or world should have analagous circumstances to ours at the present time, as to insist that every member of a family should be of the same age, and in the same state of development. There are worlds that have not yet reached the conditions of habitability by men, and worlds that have passed these conditions long since. But let them go on. There are enough left, and an infinite number in course of preparation. Some are fine and lasting enough to be eternal mansions in the sky." —*Recreations in Astronomy*, p. 214. Prof. Proctor says that "Nebulæ may be looked upon as flowers in a garden, in different stages,—one springing from the earth, another in full bloom, and another in seed-time."

Cosmogony.—The Future of Our Earth.

The cosmogony of our universe, involving the growth and decay of worlds and systems, is of all subjects the most profound, sublime, and interesting to contemplate. Not only are new worlds being ushered into existence, but old ones are disappearing from the heavens. While new stars have at times suddenly blazed forth in the heavens with incomparable splendor, where none were visible before, there are many instances on record of stars having been destroyed by fire, and vanishing entirely from our view. The history of astronomy affords no records of phenomena more startling and remarkable than that of stellar conflagrations; and when we consider what has befallen other worlds, we are naturally led to inquire whether our own may not eventually share the same fate. The Bible informs us that "the heavens shall pass away with a great noise, and the elements shall melt with fervent heat; the earth also, and the works that are therein, shall be burned up." Destruction by fire will doubtless be the ultimate fate of our world. It is prophesied by the Scriptures, and inscribed in the heavens above us. Science and Revelation harmonize on this important question, if they do not concerning any other; and both agree in pointing forward to a time when an ordeal by fire will be the final end of our world.

Here we are, in the presence of the Infinite, standing, as it were, upon the verge of eternity, and not knowing "what a day may bring forth." To quote the eloquent language of Prof. Proctor: "There is infinite darkness enshrouding and overshadowing us.

A few links of the mighty chains which bind the universe together have been traced, and others may some day be perceived, but we know that the chains are endless. We stand in the presence of many infinities, before which the soul trembles, perplexed and dismayed by infinity of mystery." But still, amid the destruction of systems, and the wreck of worlds, we have the comforting assurance of the Scriptures that "while the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night shall not cease."

We cannot tell in what way, or from what source, our earth will be destroyed by fire; but we have good reason to believe that long before such a catastrophe can occur, the earth must first grow cold, and finally arrive at that state of refrigeration through which the moon is now passing. In fact, we see in the case of the moon, a picture of what our earth will be at some future time; and I sometimes think that our satellite was placed by the Creator the nearest celestial body to our earth, not only to sway the tides of the ocean, and illuminate our nights, but also that we may read from its face what the future destiny of our world will be. Prof. Proctor says: "The moon must have cooled off six times faster than the earth, and is in the same condition that the earth will be in 2,500,000,000 years hence. The moon gives us a good idea, probably, of the way our earth will look 2,500,000,000 years from now." Then, after the life and energies of our world have become exhausted, it will doubtless arrive at that desolate condition so eloquently prophesied and described in Byron's "Darkness," when the stars shall wander, "darkling in the eternal space, rayless and pathless,"

and the "icy earth" shall swing "blind and blackening in the moonless air,"—

> "Seasonless, herbless, treeless, manless, lifeless;
> A lump of death, a chaos of hard clay."

The moon is regarded by astronomers as a dead, cold, and worn-out world, destitute of life, and in an advanced stage of physical development. Our world must eventually, through its gradual loss of heat, reach the same desolate condition; and, as Prof. Winchell, of the Michigan University, has truly said, in his "Sketches of Creation": "Every year and every day witnesses the dissipation of terrestrial warmth. While we ponder the great fact, the world is growing cold beneath our feet. The current of events is carrying us inevitably to a state of total refrigeration." In referring to the future of our earth, and the present condition of the moon, he also says: "These thoughts summon into our immediate presence the measureless past and the measureless future of our material history. They seem almost to open vistas through the eternities, and to endow the human intellect with an existence and a vision exempt from the limitations of the finite, and lift it up towards a sublime apprehension of that Supreme Intelligence whose dwelling-place is eternity." —*Geology of the Stars*, p. 31.

The Finite Duration of Worlds.—Conclusions of Eminent Astronomers.

It is now generally believed by the leading astronomers and other scientists of the world, that our earth has not existed from eternity in its present condition, and will not remain forever in the same state of development,

but that it is undergoing processes of evolution, which lead us to the conclusion that it will have its day, and at some future time cease to exist as a world. At least, this is what modern science teaches us to believe; and if the earth had a beginning, it is reasonable to expect that it will sometime have an end. This idea is entertained by the most eminent of our modern writers on science; and Prof. Simon Newcomb, of the United States Naval Observatory at Washington, in his admirable work on astronomy, recently published, says:—"All modern science seems to point to the finite duration of our system in its present form, and to carry us back to the time when neither sun nor planet existed, save as a mass of glowing gas. How far back that was, it cannot tell us with certainty; it can only say that the period is counted by millions of years, but probably not by hundreds of millions. It also points forward to the time when the sun and stars shall fade away, and nature shall be enshrouded in darkness and death, unless some power now unseen shall uphold or restore her." —*Popular Astronomy*, p. 89.

Another recent work, written by two American astronomers who rank among the most eminent authors of the world, contains the following statement, regarding the conclusions to be drawn from the nebular hypothesis:—"The widest generalization associated with it is that, so far as we can see, the universe is not self-sustaining, but is a kind of organism which, like all other organisms we know of, must come to an end in consequence of those very laws of action which keep it going. It must have had a beginning within a certain number of years which we cannot yet calculate with certainty, but which cannot much exceed 20,000,000,

and it must end in a chaos of cold, dead globes at a calculable time in the future, when the sun and stars shall have radiated away all their heat, unless it is re-created by the action of forces of which we at present know nothing."—*Newcomb and Holden's Astronomy*, p. 501.

We know that the earth, stars, and planets are "winding up their career;" but how long a time must elapse before our world loses all of its heat, becomes refrigerated as the moon is at present, and finally passes through its fiery ordeal, until it is "burned up" and destroyed, our present knowledge will not enable us to determine, and we must ever remain in ignorance concerning this question, of such momentous import to us all. "Can'st thou by searching find out God? Can'st thou find out the Almighty to perfection?" No, the ways of the Almighty are "past finding out," and we can never hope to fathom the purposes of that great Being,

> "Who sees with equal eye, as God of all,
> A hero perish, or a sparrow fall;
> Atoms or systems into ruin hurled,
> And now a bubble burst, and now a world."

The Mysteries of the Universe.—Notable Changes among the Stars.

The mysteries of the universe surround us on every side, and the further we penetrate with our knowledge, the more do we see beyond, in the contemplation of which even the imagination is bewildered, until the mind grows weary in its efforts to grapple with the unsolved problems of the universe; and at last, the words of the Psalmist compel us to acknowledge their truthful-

ness and significance: "O Lord, how manifold are thy works! in wisdom hast thou made them all." Constant changes are taking place in the star-depths, and the wonderful processes of evolution are in perpetual operation.

One of the most notable examples of the changes taking place in our firmament, is to be found in the motions of the seven bright stars forming the "Big Dipper," in the constellation Ursa Major. Here is a diagram showing the stars of the "Big Dipper" in their present position. These little arrows indicate the direction in which the stars are moving, and these dotted lines show the outline of the "Big Dipper," with which you are all familiar. You will observe that five of these stars are moving in the same direction, which shows that they are in some manner associated with each other. By a careful study of the motions of all these stars, Prof. Flammarion, a distinguished French astronomer, has been able to represent the outlines formed by them at various times in the past, and those which they will form in the distant future. One hundred thousand years ago, according to his calculations, the stars forming the "Big Dipper" were arranged in the outline of a large and irregular-shaped cross, the appearance of which is represented in the middle diagram; and one hundred thousand years hence, they will assume the outline of an elongated and inverted "Dipper," stretching over a large extent of the sky, the appearance of which is represented in this lower diagram.

The notions hitherto entertained as to the stars and the heavens, are destined to undergo a complete revolution. There are no "fixed stars." Each one of those distant suns, flaming in infinitude, is swept along in a

stupendous movement, which the imagination can hardly conceive; and your humble servant ventures to predict, that before many years have elapsed, there will be recognized among the stars a variety of constitution, and complexity of arrangements, strikingly contrasted with the general *uniformity of structure*, at present taught in most of our text-books on astronomy.

"Roll on, ye stars; exult in youthful prime;
Mark with bright curves the printless steps of Time;
Near and more near your beamy cars approach,
And lessening orbs on lessening orbs encroach.
Flowers of the sky, ye, too, to age must yield,
Frail as your silken sisters of the field.
Star after star from heaven's high arch shall rush,
Suns sink on suns, and systems systems crush,
Headlong, extinct, to one dark center fall,
And death, and night, and chaos mingle all;
Till o'er the wreck, emerging from the storm,
Immortal nature lifts her changeful form,
Mounts from her funeral pyre, on wings of flame,
And soars and shines, another and the same."

A Stupendous Problem.—Distances of the Stars.

The problem which astronomers have to solve in ascertaining the distances of the stars, is one of the most stupendous difficulty. Of all the thousands of stars which have been studied, astronomers know the distances of about twenty, and these are known only approximately, being the supposed distances *within* which it is believed they *cannot* be, but *beyond* which they *must* be, although the exact limits cannot at present be ascertained, owing to the immense distances which separate them from our earth. The nearest star is so re-

mote that its light requires 3½ years to reach us, while the light of the pole-star is 50 years in reaching us from that distant orb; so that if the light of this star was extinguished to-day, 50 years would have to elapse before we should be aware of the fact!

The mathematical principles involved in determining the distance of a star, are essentially the same as those employed by the surveyor when he wishes to measure the width of a stream which he cannot cross; only, with the astronomer the problem is rendered much more complicated from the fact that he is unable to procure a base-line of the sufficient length to meet his requirements; and even the diameter of the earth's orbit is not great enough to use in measuring the distances of the stars, with very few exceptions. To learn the distances of the stars, it is first necessary to determine what is known as a star's parallax, or its angle of direction when viewed from two opposite points in the earth's orbit, and this is what renders the problem so extremely difficult; for nearly every star in the heavens that has been examined for the purpose of learning its distance, has failed to show any parallax whatever, and in the few instances where a parallax has been recognized, the angle is found to be exceedingly small. No star in the heavens has a parallax equal to one second, but all thus far determined are below even this small angle.

The star which gives the greatest parallax of any, and is believed to be the nearest to our earth, is Alpha Centauri, a first-magnitude star in the southern heavens, and never visible in our latitude. But even this star's parallax is only $\frac{9}{100}$ of a second, which corresponds to a distance of 221,000 times the sun's distance from our

earth, or over twenty trillions of miles! And this, remember, is *the nearest star* at present known to astronomers. The earth's orbit, seen from this star, would appear the same as a circle six-tenths of an inch in diameter, seen at the distance of one mile; and the radius of that orbit,—or the distance which separates our earth from the sun,—would be hidden by a fine thread, or spider's web, $\frac{1}{25}$ of an inch in diameter, held 650 feet from the eye! "That is to say, a line 184,000,000 miles long, looked at broadside, would shrink into a mere point. If our sun were removed to that distance, it would shine with a light only equal to that of the north star, while its parallax would be but the $\frac{1}{100}$ of a second."

There are stars so remote that their light cannot reach us in less than 10,000 years. To traverse the Milky Way, of which our own solar system forms a part, light requires 15,000 years; and to reach us from some of the distant nebulæ, it must travel for 300 times that period, or nearly 5,000,000 years! It is in the contemplation of such facts as these that we fully realize our own insignificance in the scheme of creation, and feel prepared to exclaim, with the Psalmist: "When I consider Thy heavens, the work of Thy fingers, the moon and the stars which Thou hast ordained, what is man that Thou art mindful of him? and the son of man that Thou visitest him?"

Concluding Remarks.—"The Veil Lifted."

In concluding my lecture, would it not be well to lift the veil which shrouds us from futurity? With boldness, yet with humility and reverence, let us proceed to do so.

Who can tell what glorious discoveries will have been made in astronomical science after another period of six thousand years has rolled slowly away? Looking into the distant future, through the dim vista of years, we can, in imagination, picture to ourselves the patient astronomer, still at his task, watching and waiting, and grappling with the grand problems of the skies. We are apt to dismiss reflections of this nature, thinking that but very little remains for the astronomer to accomplish. But there are yet "more worlds to conquer." Even now hundreds of grand problems are presented to astronomers for solution which escape their notice; and before another century has rolled away, in thousands of lofty observatories, with their gigantic telescopes peering heavenward, there may yet be made some of the most brilliant discoveries ever chronicled in the annals of astronomical science. The watch-towers of the heavens now cover the whole earth, and the sentinels never sleep. Paradoxical as it may seem to you, no star, or cluster, or constellation can ever set. It escapes the scrutinizing gaze of one astronomer, only to meet the equally piercing glance of another. Hark! from out the distant star-depths, and the highways of the planets, eastward, westward, northward, southward, peals the solemn mandate, "Onward!" This is now the watchword of the astronomer; and although the key which unlocks the hidden mysteries of the universe still remains far beyond our reach, yet, while the amazing star-depths lie before us, with their wonders and perplexities—unfathomed and unfathomable—the true astronomer will never cease his efforts to interpret rightly the grand lessons which they are meant to teach us,

until that time shall come, in the far-distant future, when "KNOWLEDGE SHALL BE PERFECTED, AND SOVEREIGN POWER TRIUMPHANT."

COMPLIMENTARY TESTIMONIALS.

"Mr. Bartlett began the study of astronomy when thirteen years old, and has sought a knowledge of the heavens under all manner of discouragements. The success he has achieved, and the position he occupies among astronomers, warrants the belief that his lecture will be an entertaining one, and Mr. Bartlett a lecturer whom lyceum committees, in search of attractive novelties, would do well to negotiate with."—*Detroit Free Press.*

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PROF. LEWIS SWIFT, Astronomer, Rochester, N. Y.

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